

Perception and reaction to floor impact noise in apartment buildings: A qualitative approach

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Running title: Perception and reaction to floor impact noise

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Summary

This study used grounded theory to understand how apartment building residents perceive and react to floor impact noise from upstairs. In-depth interviews with a heterogeneous group of 14 participants were conducted, and the acquired data were analysed to develop a conceptual model for describing perception and reaction to floor impact noise. It was found that floor impact noise had diverse sources, with the majority originating from footsteps. The participants negatively perceived the noise as annoying and disturbing, and sleep disturbance was reported the most frequently. Cognitive and avoidant coping strategies were initially adopted, and complaints were only thereafter registered if the noise persisted. It was also observed that exposure to the noise led to self-reported health problems and concerns. The developed conceptual model highlights potential intervention measures for controlling noise perception and reactions to floor impact noise.

Keywords: Floor impact noise, Perception, Reaction, Apartment living, Non-acoustic factors

PACS no. 43.50.Jh, 43.50.Qp, 43.55.Hy

1. Introduction

Noise has adverse physical, physiological, and psychological effects on human [1]. Particularly, human walking noise in residential buildings is a major cause of annoyance with the noise level being a significant contributory factor [2, 3]. Therefore, acoustical and psycho-acoustical measures have been investigated to explain perception of floor impact noise [4, 5].

The variation of each individual's reaction to noise cannot be fully explained by acoustic factors [6]; however, few studies have been conducted to explain the effect of non-acoustic factors on people's perception of floor impact noise. Dissatisfaction with the indoor noise environment of a residential building was found to be closely associated with annoyance caused by floor impact noise [2]. Ryu and Jeon [7] introduced noise sensitivity as a significant indicator of annoyance. They explored the correlation between noise sensitivity and annoyance ratings under indoor residential noise and outdoor road traffic noise, respectively. Noise sensitivity was found to significantly affect annoyance induced by both indoor and outdoor noises, with the effect on the former being more pronounced. In addition, the ethnicity of an individual was suggested to contribute to their subjective reactions to floor impact noise [3]. The foregoing study compared the loudness evaluations of German and Korean subjects and found the latter to be more sensitive to floor impact noise. Recent survey reported that noise sensitivity had a direct impact on disturbance and an indirect impact on annoyance of floor impact noise [8]. Contrary to building noises such as floor impact noise, a number of studies have investigated the effects of non-acoustic factors on people's perception and reaction to environmental noises. Earlier studies have suggested that demographic factors had little effect on the incidence of annoyance [6, 9, 10], whereas attitudinal variables such as attitudes to noise sources and authorities responsible for noise control have been emphasised as significant factors [11-14]. Moreover, noise sensitivity has been acknowledged as a crucial determinant of

annoyance under exposure to environmental noise [15, 16]. Close links among noise perception and reaction have been reported [12, 14, 17-19]. Fyhri and Klæboe [17] found a relationship between noise annoyance and health complaints, consistent with the earlier findings [12, 18]. Coping capacity and coping behaviours were suggested to be closely correlated with noise annoyance and noise-associated health risks [18, 19]. Pennig and Schady [14] particularly suggested that a higher coping capacity decreased the level of annoyance. In addition, Kroesen, Molin and van Wee [13] found negative attitudes to a noise source adversely affected coping capacity. However, these various non-acoustic factors have not been applied to the issue of building noises including floor impact noise.

The aim of the present study was to establish the extent to which non-acoustic factors underlie people's perception and reaction to floor impact noise in apartment buildings. The key non-acoustic factors were identified through semi-structured interviews with a sample of adult residents living in apartment buildings by adopting a methodology of grounded theory [20]. The rest of this paper describes the procedure of data collection and analysis, and presents the results together with some reflective comments in light of findings from the previous studies. Recommendations are also made for further research.

2. Methods

A qualitative approach was used to gain an understanding of perception of floor impact noise and provide insights into the issues on noise produced by neighbours. The study was carried out based on grounded theory as outlined by Corbin and Strauss [20] because this methodology permits a general idea of the area in the beginning of study. Grounded theory allows substantial data and insight in research data to be yielded, and is useful to comprehend underlying mechanisms of certain phenomena. Use of this methodology for a qualitative study needs a lot of cautions as it is difficult to detect researcher's bias throughout whole period of

data analysis and to establish reliability or validity of approaches. Thus, multiple researchers should cooperate to analyse data and build a theory and saturation of information should be reached [20]. Grounded theory has been adopted in the research fields of soundscape and noise perception [21, 22]. The transcripts and audio recordings of the interviews were used to determine the nuances of individual emotions and experiences.

2.1. Participants

The interview invitation was posted online to be viewed by diverse people and the basic aim and procedure of the study, monetary compensation for the time were explained. All participants lived in Seoul, Korea or its satellite cities. As listed in Table I, a heterogeneous group of 14 residents comprising five males and nine females participated in the study. The participants had been informed that they would be interviewed about their experiences of exposure to floor impact noise in their current dwellings. The age of the participants ranged from 21 to 55. Among the participants, nine lived with one or more children; nine rented their apartments and five owned theirs. The number of bedrooms in their apartments ranged between one and five. Five of them reported that their upstairs neighbours had one or more children. Thirteen participants had lived in their current apartments for more than one year and one had lived in her apartment for 10 months. The participants spent an average of 14 hours a day (standard deviation = 3.8) in their homes.

Table I

2.2. Interview procedure

Semi-structured interviews that lasted for 30~90 minutes were conducted. Each interview was preceded by the participant voluntarily signing their consent for involvement, audio recording, confidentiality, and anonymity. The participants were required to complete a

questionnaire before the interviews, regarding their demographic characteristics and housing conditions. Guiding questions for the interview were developed mainly based on the previous findings of non-acoustic variables affecting human perception and reaction to noise [11, 13, 18, 23, 24]. The questions were open-ended and progressively depended on responses of the participants. The participants were encouraged to freely express their personal thoughts and experiences concerning exposure to floor impact noise.

2.3. Data analysis

Each interview was manually coded line by line using the participant's own words and immediate expressions. The codes were classified into several themes, and those with significant relationships and similarities were grouped together in higher-order categories. The resultant themes and categories were again compared with the raw data (i.e., the original transcripts and audio recordings), memos, and other theoretical ideas [20]. This manual procedure was repeated several times. No new insight was obtained after the interview of the 13th participant, and theoretical saturation [20] was thus considered to have been attained after one additional interview. The final re-coding was carried out using a qualitative data analysis software (NVivo 10). The numerous processes of the manual and computerised coding enabled a comprehensive analysis of the data and an identification of the core themes and categories.

3. Results and discussions

Analysis of the data identified 14 themes. Table II lists the counted frequency of the final codes. The key themes were grouped into four key categories. The characteristics of the noise sources to which the participants had been exposed were classified into three themes under the tag of "noise exposure". Annoyance and disturbance were grouped as "noise perception". The coping strategies and health complaints were grouped as "noise reaction". The last category,

“intervening conditions” included four themes which represented underlying personal and attitudinal variables that interacted with other factors. The term “intervening condition” suggested by Corbin and Strauss [20] includes the underlying psychological factors that were observed to interact with the other categories.

A conceptual model (Figure 1) was developed to illustrate relationships amongst the four categories. Acoustic variables are described in white boxes and non-acoustic variables are presented in grey boxes. The model was developed mainly based on previously suggested models of perception and reaction to environmental noise [11, 18, 23]. Reciprocal relationships among noise perception and noise reaction are hypothesised in Figure 1. This reciprocal relationship was hypothesised as it was found that the two themes in noise perception (annoyance and disturbance) resulted in increase of different types of noise reaction (copings and health complaints), and increased noise reaction again affected an increase of noise perception. Previously, the path between noise perception and noise reaction was theoretically suggested [11, 18, 23] and empirically tested by studies on annoyance due to aircraft and railway noises [13, 14]. Noise exposure, noise perception, and noise reaction are tied in a big loop of dotted-line, and intervening conditions are hypothesised to be reciprocally related to this whole loop representing intervening conditions have reciprocal relationships with all other categories. Lercher [18] suggested a person-environment relationship in his paper, explaining it affects stress appraisals and coping process. Guski [11] also suggested moderating effects of personal and social factors on noise annoyance. Similarly, the themes in the intervening conditions (attitudes to neighbours, attitudes to authorities, noise sensitivity, and past experience) have been found to be closely and reciprocally linked to the themes in other categories. Attitudinal variables and noise sensitivity have been known to have close relationships with the themes in other categories (e.g., annoyance, coping) [11, 13, 14, 23]. There was also extended findings in this study regarding effects of intervening conditions on

noise exposure. For instance, a problematic relationship with upstairs neighbours (which is regarded as one of attitudes to neighbours) may increase the occurrence of retaliatory noise from upstairs.

Table II

Figure 1

3.1. Noise exposure

Floor impact noise sources are classified into lightweight and heavyweight impact sources based on their physical characteristics such as the impact force and mechanical impedance [25]. Lightweight impact noise includes walking in high-heeled shoes and dropping of lightweight objects, and heavyweight impact noise is mainly caused by footsteps (e.g., children's running or jumping). Furthermore, lightweight impact noise is dominated by high-frequency components, whereas heavyweight impact noise has a dominant sound energy at low frequencies below 100Hz [4]. The noises produced by different impact sources have varied physical and psycho-acoustical characteristics. Consequently, the subjective reaction of an individual to floor impact noise is affected by the type of source [4, 5].

The various noise sources reported by the participants were classified into lightweight or heavyweight impact sources. The majority of the noises that the participants had frequently been exposed to were heavyweight impact noise such as adults' walking and children's jumping and running. This was mainly because Koreans do not wear shoes in their homes and barefoot walking on the floor often causes heavyweight impact noise. Among the 14 participants, 10 mentioned footsteps, which agreed with the previous findings that footsteps were the most frequent noise source in apartment buildings [2, 25, 26].

P6: A child keeps running and I can hear people's walking. I suppose it would be less noisy if they wore indoor shoes or put a mat on the floor, but they don't do anything.

P14: A boy (living upstairs) makes noise a lot. His footsteps are very noisy. He makes noise even after midnight.

Lightweight impact noise sources were also mentioned by the participants, although less frequently compared to heavyweight impact sources. This was because, unlike heavyweight impact noise, the dominant sound energy produced by lightweight impact noise sources can be easily reduced by acoustical treatments such as floor coverings and resilient isolators [27]. The sources of lightweight impact noise observed in this study included scraping of furniture or items against the floor, scratching of the floor by dogs, and dropping of lightweight items.

P2: There's something like the noise of furniture scraping at 11 or 12 at night. Or hitting or dropping noise; it sounds like they (upstairs neighbours) are hitting their floor or dropping something to disturb us.

Most environmental noise sources such as road traffic and wind turbines continuously produce noise with high pressure levels. In contrast, neighbouring noise such as floor impact noise is intermittent and occur irregularly because the noise events and their frequencies are significantly dependent on the behaviours of neighbours. A recent study on combined industrial and road traffic noises found that the noise was less tolerable in the early morning and evening [28]. Most of the participants of the present study also reported that they had heard floor impact noise at night or in the morning. The significantly lower level of ambient noise at those times could explain the more frequent complaints about night or morning noises.

P3: Before I go to sleep, when I'm lying on my bed at night, I can hear the noise...Sometimes early in the morning as well.

P14: I can hear the noise at night, but also at 7 to 8 in the morning... The noise disturbs my sleeping...It wakes my baby up, he cries, it's hard to get him to sleep again.

3.2. Noise perception

Perception and reaction to noise can be explained by stress theories [18, 23]. One means of doing this is the transactional approach [29], by which Lercher [18] described the noise-health relationship as a continuous process of appraisals, coping, and reappraisals. According to this model, the perception of noise (i.e., the perceived annoyance and disturbance) can be described as a primary appraisal [11, 18]. In the present study, most of the participants reported that they had negative perceptions of floor impact noise, which they described in terms of the annoyance and disturbance. This is unsurprising given that noise from neighbours is the second major cause of noise annoyance in living environments [26], and floor impact noise was found to be the most annoying source in apartment buildings [2]. In most cases, the participants expressed their negative emotions together with complaints about their current apartment buildings or concerns about the health risks. Moreover, it was observed that those who had experienced high level of noise annoyance had coped very actively with the noise problems. For example, they had contacted or visited their upstairs neighbours, called security officers to complain about the noise, or made official complaints to relevant authorities. This indicates that annoyance caused by floor impact noise is closely associated with the adoption of coping strategies, as revealed by previous studies on environmental noise [11, 23].

P6: They (upstairs neighbours) make noise anywhere, in the living room, in the bedroom, and even in the bathroom... Now I can understand those who killed their neighbours on TV. It's very stressful... It (the continuous noise) is so much stressful and I think it's very harmful to health physically and mentally.

P8: I've tried everything to solve this noise problem... Of course I've called relevant authorities to make complaints... I called the police at first... I've recorded the noise to make the evidence, I thought they couldn't deny, but they denied, they said the noise wasn't theirs...they kept making noise.

On the other hand, some participants reported noise annoyance less than others and that they rarely made noise complaints.

P1: It is true that I'm annoyed sometimes, but I just try not to mind too much... I've made a noise complaint once but I just don't want to complain about it again, to them or anywhere else (to authorities).

P3: I haven't complained about it. Sometimes I think about moving house, maybe to the top floor because it'll be quieter. Anyway, I can understand why they (upstairs neighbours) make noise, and try to be sympathetic.

The different level of noise annoyance among the participants can be explained by both acoustic and non-acoustics factors. Noise annoyance in a building is affected by physical attributes such as the noise source, floor thickness, and dynamic properties of the floor [3, 5]. Non-acoustic factors such as noise sensitivity, attitude to noise sources, demographic characteristics, and situational factors (e.g., time spent at home) contribute to subjective perception of noise [6, 9, 10, 24]. Unlike the case of environmental noise, the effects of non-acoustic factors on perception of floor impact noise have not been empirically investigated. Further study is therefore required to validate the previous conceptual models regarding non-acoustic factors using empirical data on perception of floor impact noise.

Another major negative consequence of exposure to noise is related to the disturbance. It has been reported that exposure to environmental noise disturbs various human activities such as speech, watching TV, listening to the radio, and sleep [30, 31]. Many participants of the present study also reported disturbance caused by floor impact noise. They reported that noise induced by their upstairs neighbours had disturbed various activities in their homes, such as studying, reading, watching TV, and sleeping. Interestingly, the descriptions of their disturbance experiences usually included wordings of noise annoyance. This shows that noise disturbance is closely associated with perceived annoyance, thus confirming the earlier

conceptual model that suggests a reciprocal relationship between disturbance and annoyance [23].

P12: When I read some books in my living room, or when I concentrate on something, I'm disturbed by noises from upstairs; it easily makes me lose my concentration.

The most frequently disturbed aspect of the home lives of the participants was their sleeping. Given that the majority of the participants complained of noise at night or in the morning, it was deduced that sleep disturbance was most prevalent. Among the 14 participants, eight reported that their sleep had been disturbed by noises from upstairs. Hume, Terranova and Thomas [32] found that noise sensitivity at night was significantly higher compared to during the rest of the day and suggested stricter enforcement of night-time noise policy. The higher night-time noise sensitivity can be explained by the close link between sleep and quieter ambient noise.

P1: Of course, I can understand it (noise from upstairs) during the afternoon, but I'm very annoyed with it at night because it's quieter, so I can hear it far more at night.

P6: The noise disturbs our sleep and rest. We don't have to wake up at 5 in the morning but, that short and strong noise always wakes us up. I get angry and can't get back to sleep... We can't take proper rest because of the noise, it's very difficult for us.

3.3. Noise reaction

As hypothesised in Figure 1, two major noise reactions (i.e., coping and health complaints) were found to interact with the two noise perceptions (i.e., annoyance and disturbance) when the residents were exposed to floor impact noise induced by their upstairs neighbours. As Lercher [18] described in his model, noise annoyance and disturbance influence coping and noise-associated health risks and vice versa. Coping is an important strategy to deal with noise

annoyance and disturbance, and negative health effects are some of the crucial long-term consequences of perception and response to noise [11, 18].

3.3.1. Coping

Coping includes all the cognitive and behavioural efforts involved in managing noise annoyance [11, 18, 29, 33]. Cognitive coping is an indirect coping strategy which includes denial, repression, and suppression, while behavioural coping is a more direct way of coping that involves problem-solving behaviours in order to reduce or manage distressing emotions [33]. As hypothesised in Figure 1, the relationship between intervening conditions and coping, some underlying attitudinal factors (e.g., attitudes to upstairs neighbours) were observed among the majority of participants who reported cognitive coping.

P1: Of course, I can hear it (noise from upstairs) but I try not to mind too much.

P2: I'm scared. You know, there have been some murder cases these days... We (husband and I) just try not to hear it.

Behavioural coping included avoidant and vigilant coping. Avoidance aims at diverting one's attention from the stress to get away from it, whereas vigilant coping directs the attention to the stress source to prevent or control it [33]. The present study divided the behaviours that were made to avoid noise exposure and registering noise complaints as avoidant coping and vigilant coping respectively. Hume and Thomas [34] reported that people rarely complained about aircraft noise because they assumed that their complaints would yield no results from the relevant authorities. Another study on the annoyance caused by aircraft noise found that the low success expectation caused disparity between incidences of the annoyance and the corresponding complaints [35]. Likewise, it was found that avoidant coping was mainly employed for the first several times when floor impact noise was heard. Frequently used

avoidant strategies were going out, using earplugs, turning up the volume of the TV/music, and trying to concentrate on other activities.

P5: I suppose that it's better to go out not to hear the noise, if possible, rather than visiting them (upstairs neighbours to complain).

P12: My wife turns up the volume of the TV.

Some participants had registered noise complaints (i.e., vigilant coping), which is one means of coping with noise and noise annoyance [36]. Residents in apartment buildings are likely to make noise complaints since their neighbours are the main noise sources, unlike in the case of environmental noise. Additionally, the unpredictability of noise exposure may also cause them to make more complaints. This is because people are likely to complain about the unusual conditions of the noise rather than noise annoyance itself [37]. The study participants initially made indirect noise complaints by contacting security officers or the block managers, rather than directly contacting the upstairs neighbours. This is in agreement with the argument of Gass and Neu [38], who insisted that people tended to perceive indirect complaints as a positive approach. As the frequency of the complaints increased, the approach also changed into direct contact with the neighbours or making official complaints to authorities, as in the case of those who had observed no significant change in the noise disturbance after indirect complaints.

P10: I had turned on some music while I was sleeping not to hear the noise, and tried to use earplugs as well, but all of them were not helpful for sound sleep...I had called a security officer, asked for an official announcement within the building, but nothing had changed, so I called police...he (upstairs neighbour) started making more noise after then, he jumped purposely after the (policemen) had went away...I called the National Environmental Dispute Resolution Commission...it took a long time and many stages.

Nykaza, Hodgdon, Gaugler, Kreckler and Luz [39] reported that people who had made complaints about military noise reported higher noise annoyance than those who had not

complained about the same. Vigilant coping can be used to reduce the stress level when favourable outcomes are expected, whereas negative emotions might be provoked by the realisation that nothing can be done to improve the situation [33]. Some participants reported that they had experienced significantly reduced noise exposure after making a number of complaints to their neighbours and authorities. Their narratives indicated low noise annoyance and relatively weak negative emotions, or even a positive feeling about their apartments, the indoor environment, and their upstairs neighbours. In contrast, some other participants reported that their complaints had not been effective in managing the noise problems. Their narratives indicated high noise annoyance levels and strong negative emotions towards the noise issue and their upstairs neighbours. An unsuccessful coping can also increase the noise annoyance [40], and making further complaints might become unreasonable after being previously ignored [37]. It is therefore necessary for authorities to establish an effective procedure for dealing with complaints on floor impact noise. Here, it is also implied that coping has a significant interactions with attitudinal variables (i.e., intervening conditions).

3.3.2. Health complaints

Exposure to noise has been found to cause health problems [26, 41]. Road traffic noise was also found to raise complaints about nervousness and headache [17] as well as disturbed sleep, which increases the secretion of stress hormones [41]. In addition, annoyance caused by the noise of wind turbines was found to induce negative health complaints and psychological distress [12, 31]. Likewise, the present study participants had felt that exposure to floor impact noise caused health problems.

P7: I lost so much weight because I've been so stressed by the noise.

P12: I have been experiencing dizziness before moving into this apartment, and it has become worse because I've been hearing the noise continuously.

Lercher and Kofler [42] reported that residents exposed to noise above 55dBA worried more about their health and had poorer health ratings. Kroesen, Molin and van Wee [43] found that annoyance induced by aircraft noise significantly increased concerns about the negative effects on health due to noise. Similarly, participants of the present study expressed concerns about the negative effects of floor impact noise on their physical and mental health. This included concerns about stress, mental problems, and general health issues such as fatigue, headaches, and indigestion.

P4: If I were exposed to noise constantly, then I would have some mental problems.

P5: I believe floor impact noise is really bad for health...noise at night, when we are supposed to sleep, will make us very tired.

3.4. Intervening conditions

Corbin and Strauss [20] introduced the term “conditions” as one of the basic components of a paradigm that could be developed in the axial coding phase to explain relationships among categories that emerge. According to Corbin and Strauss [20], conditions provide further answers to questions about why, where, how, and what happens. The present study identified four key intervening conditions that had positive or negative intervention effects on the participants’ noise perception and reaction. The intervening conditions included attitudes to authorities and neighbours, noise sensitivity, and past experience.

3.4.1. Attitudes to authorities

It was observed that negative attitudes to authorities had been developed because of unsuccessful complaints. Moreover, the attitudes to authorities affected the individual noise annoyance and coping. Some participants expressed their negative attitudes to governmental authorities, due to the unpleasant procedure of making official complaints or their getting unsatisfactory results from the complaints. Guski [11] previously suggested that negative

attitudes of residents can be reduced by authorities showing willingness to communicate and cooperate with the complainants. A participant revealed her negative attitude to the government particularly on the lack of relevant policies regarding floor impact noise. This suggests that proper policies including restrictions on indoor activities and higher standards of building construction are needed to deal with the increasing number of noise complaints. Construction companies were another authority that some of the participants had negative attitudes towards. It was believed that poor sound insulation in buildings was a major cause of the problem and that construction companies were primarily responsible for this. Moreover, it was believed by many participants that acoustic comfort can be afforded by properties built by major construction companies.

P6: The centre (Floor Noise Management Centre) is of no use. They're not for the proper solution... I don't want to call them (the authorities) again.

P7: Some regulations should be made for this issue. I've contacted 12 (government) officials who are working on legislation (to suggest legislation on the noise issue).

3.4.2. Attitudes to neighbours (noise source)

Attitudes to the noise source has been found to significantly affect annoyance induced by environmental noise [9, 11]. The present study revealed that an attitude to neighbours was developed throughout the period of noise exposure, disturbance, and noise annoyance. In addition, the attitude affected the residents' coping strategy. This study also observed that relationship problems with the neighbours had influences on the negative attitude. Additionally, relationship problems were found to be caused sometimes by the adopted vigilant coping strategy. Some participants reported that they developed relationship problems with their upstairs neighbours after making noise complaints. Their complaints caused their neighbours to make more noise, namely, retaliatory noise. It can therefore be said that

relationship problems between neighbours might change the characteristic of the noise source into retaliatory noise, which is listed in Table II as one of the three themes of noise exposure. The retaliatory noise again increased the annoyance and prompted further complaints. Health complaints can be explained by not only noise annoyance, but also the stress caused by the relationship problems, including exposure to retaliatory noise.

This study also identified very different kinds of attitudes to neighbours. One participant reported that he had never complained about noise to his neighbours and does not intend to do so in the future. This was because he had received noise complaints from his downstairs about his children's running neighbours and knew how difficult it was to keep the children not to run. Although Maschke and Niemann [26] insisted that neighbour noise annoyance could be heightened by the hearer's knowledge of the noisemaker, the present study observed that having empathy with neighbours could decrease the level of annoyance and the frequency of complaints. It is therefore worthwhile discussing how a positive relationship with neighbours might mitigate negative noise perception as well as the vigilant coping behaviours that may cause relationship problems. This would promote closeness and reduce disputes among neighbours in apartment buildings.

P14: I used to go upstairs or ring them to ask them to be careful, but I gave up. I've already complained so many times but they've been the same.

P13: They (upstairs neighbours) make noise until late but I'm trying to be sympathetic... I haven't complained about it (the noise) and I won't, because I know how it feels (to receive noise complaints)... I know it's very hard to control them (children).

3.4.3. Noise sensitivity

Noise sensitivity has been noted as a significant indicator of annoyance caused by environmental noise [9, 11]. Similarly, annoyance induced by floor impact noise was found to

be affected by noise sensitivity [7]. The present study confirmed the close link between noise sensitivity and noise perception. Participants who were more sensitive to noise reported more annoyance and disturbance caused by floor impact noise. Noise sensitivity has actually been acknowledged as a stable personality trait that includes different attitudes towards a wide range of environmental sounds [44]. The present study expanded this notion, suggesting that an individual's noise sensitivity can be heightened by circumstances such as repeated exposure to noise, change of situation (e.g., new-born baby in the house), and the presence of other noise-sensitive family members.

P9: Before I moved in, I wasn't sensitive (to noise) at all, but after experiencing this (exposure to floor impact noise) for a long time, I became very sensitive to it (noise).

3.4.4. Past experience

Rabkin and Struening [45] noted past experience as a factor that contributes to one's perception of stressful events. Ipsen [46] also highlighted the importance of the knowledge that an individual gains through life, and Fyhri and Klæboe [47] suggested that careful attention should be given to people who had been previously affected by noise. It was also obvious from the present study that previous exposure to floor impact noise affected one's noise perception and reaction. Having past experiences of being exposed to the noise means having experienced most of the key themes that the present study discovered, such as annoyance, disturbance, different coping strategies, and health risks. Participants who had experienced floor impact noise either in their previous apartments or from previous neighbours in the current apartments reported that they had become more sensitive to noise, got more annoyed and disturbed by it. More narratives of negative attitudes to authorities and neighbours, coping, and health complaints were reported by them. There are thus no doubts that people with past experience of noise exposure are more likely to have negative perception and reaction to noise.

P14: We (my husband and I) suffered so much (from noise problems) in the previous building. That (noise problem) was one of the biggest reasons that we moved house... I suppose we became more sensitive than before.

4. Conclusions

This study provided understanding of people's perception and reaction to floor impact noise inside apartment buildings in South Korea. In-depth interviews of apartment building residents in South Korea were conducted and the narratives of the interviewees were analysed based on grounded theory. The analysis results were used to develop a model, which yielded valuable insight into residents' perception and reaction to floor impact noise, and enabled description of the relationships among the acoustic and non-acoustic factors. The hypothesised conceptual model contained both acoustic and non-acoustic variables and presented relationships within the variables. It would be beneficial to authorities and construction companies for reducing floor impact noise and negative perception and reactions to it. The findings of this study can also be extended to the previous conceptual models for explaining human perception of environmental noise [11, 23].

In this study, floor impact noise sources in apartment buildings were classified into heavyweight and lightweight sources, and footsteps were observed to be the source that the study participants had most frequently encountered. Most of the participants reported night-time and morning noises, which disturbed their sleep. Although it is challenging for floor impact noise, long-term recordings and field measurements would facilitate further understanding of the relationship between noise level and its subjective perception.

This study also revealed that apartment building dwellers adopted behavioural coping strategies more frequently than cognitive approaches, which was because the type and location of the noise source could be easily recognised. However, questionnaire surveys are recommended that include questions about the perceived control or coping capacity, with the

purpose of comparing the effects of cognitive and behavioural coping strategies on the perception of floor impact noise. It was also found that avoidant coping strategies were more likely to be employed at the beginning of the exposure to noise. Vigilant coping contained making indirect and direct complaints; direct noise complaints were registered when the noise problem were not effectively solved by indirect complaints. In addition, the individual's attitudes to relevant authorities and the neighbours (noise source) evolved throughout the whole experiences of noise exposure. Some of those who had relationship problems with their upstairs neighbours had exposed to retaliatory noises. In contrast, empathy with the upstairs neighbours tended to prompt the use of cognitive or avoidant coping strategies rather than making noise complaints. Noise sensitivity and past experience were also suggested to affect the level of noise annoyance. In particular, noise sensitivity was found to be increased by repeated exposure to noise, change of situation, and other noise-sensitive family members.

The limitations of the present study are recognised. Firstly, the apartment buildings where the participants lived had different floor structures, with the newer buildings having thicker concrete slabs. In addition, physical characteristics (e.g., the dynamic stiffness) of the resilient isolators used in the floor structures of the buildings differ [48]. Further study is thus necessary to compare human perception and reaction to floor impact noise across various types of floor structures. Secondly, theoretical models of environmental noise [11, 23] were recently validated through social surveys regarding airplane and railway noises [13, 14]. Likewise, the identified themes and the conceptual model developed in this study requires validation by empirical data obtained through questionnaire surveys with a larger sample. Thirdly, the present study did not consider lightweight buildings such as wooden structures and only focused on heavyweight buildings since it is the major type of residential building in South Korea. In addition, there might be cultural factors that determine noise source, periods of noise exposure, and coping strategies. For example, unlike in Western countries, heavyweight

impacts are commonly regarded as a noise source in Korea because most Koreans do not wear shoes in their homes. Further study is therefore also required to investigate human perception and reaction to indoor noise across different building types and various cultural and social groups. Finally, any notable relationship between demographic factors and information of the interviewees (e.g., children in residence, length of residency) and the key variables were not found in this interview study. It is recommendable to investigate significant demographic factors that have influences on perception and reaction to floor impact noise in future studies as several demographic factors including household size, residents with children, or house ownership have been suggested to have effects on noise perception or reaction [18, 47, 49].

Acknowledgement

This research was supported by a grant from a Strategic Research Project (A study on noise reduction solution for adjacency household in apartment house) funded by the Korea Institute of Civil Engineering and Building Technology.

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Table I. Demographic and dwelling information of study participants ($N = 14$).

Age	Gender	Housing status	Property age (yrs)	No. of bedrooms	Child(ren) in residence	Child(ren) upstairs	Length of residence
37	F	Owned	10~15	1	Yes	Yes	6 years
35	F	Rented	5~10	2	Yes	No	5 years
34	M	Rented	10~15	1	No	Yes	1 years
30	F	Rented	< 5	4	Yes	No	4 years
37	F	Owned	5~10	3	Yes	Yes	7 years
48	M	Rented	15~20	1	No	Yes	7 years
53	F	Owned	15~20	5	No	No	15 years
55	M	Owned	5~10	3	No	No	8 years
21	F	Owned	5~10	2	No	Yes	6 years
41	F	Rented	< 5	4	No	Yes	10 months
30	F	Rented	10~15	3	No	No	3 years
36	M	Rented	> 20	3	Yes	No	1 years
33	M	Rented	< 5	2	Yes	No	3 years
36	F	Rented	10~15	3	Yes	No	2 years

Table II. Frequency of final codes in emerged themes and categories.

Category	Theme		Frequency	
Noise exposure	Heavyweight impact noise		86	
	Lightweight impact noise		61	
	Retaliatory noise		33	
Noise perception	Annoyance		128	
	Disturbance		117	
Noise reaction	Coping	Behavioural	Vigilant coping	114
			Avoidant coping	93
		Cognitive		23
	Health complaints	Health problems		51
		Health concerns		43
	Intervening conditions	Attitude to neighbours (noise source)		
Attitude to authorities			95	
Noise sensitivity			66	
Past experience			42	

Figure captions

Figure 1. The conceptual model of perception and reaction to floor impact noise.

